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BARREL AND DISK SEED SCARIFIERS

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INTRODUCTION

The development of various new legume crops by the United States Department of Agriculture and the State experiment stations has brought to the fore the problem of scarification of hard seeds. For sometime past the problem of scarifying sweetclover seed has been acute, and during the past years the introduction of various species of *Crotalaria* and *Lespedeza* has given added interest and need for a further development of seed scarifiers. It is obvious that the commercial development of such crops, no matter how valuable otherwise, will be hindered unless a cheap and simple method is found to render these seeds easily germinable.

To supply the need for a seed scarifier adapted to use on the individual farm, the barrel-type machine described on later pages was devised.[1] The disk-type scarifier, which is more costly, was developed to meet the need of agronomists for a machine of larger capacity than the barrel scarifier. The disk scarifier may be also suitable for work of a commercial scale.

HARD SEED

Many plants have seed that upon ripening and for sometime after, will not germinate under conditions to which they are normally subjected. In the case of legumes, this is due to what is known as hard seed. By this term is meant seed that have a seed coat which is impervious to water and will not germinate until it is made permeable by a natural breaking down of the cells with aging, or by abrasing or rupturing it by artificial means.

[1] The barrel and disk scarifiers were designed and built and the tests with them were conducted by the Bureau of Agricultural Engineering. All seed were furnished and all germination tests were made by the Bureau of Plant Industry, which also conducted some of the tests with concrete mixers.

Some legume crops such as cowpeas and soybeans, have little or no hard seed. Others, like red clover and alfalfa, have more or less hard seed but seldom a large proportion. In the case of these latter crops most of the hard seed are usually made permeable to water by the abrasion occasioned by the process of threshing and hulling. Crops like crotalaria, *Lespedeza sericea*, and sweetclover have a high percentage of hard seed, which in several species of *Crotalaria* averages from 80 to 90 percent even in seed that has been threshed with an ordinary thresher.

In the case of wild legumes, practically all have a high percentage of hard seed. This seems to be one of nature's ways of insuring against unfavorable seasons in which no seed may be produced, as the hard seed remain in the soil without germinating for 1 or more years.

It should be pointed out that the hardness of seed coats in different varieties of legumes differs widely. In red clover, the seed coat is easily abrased and scarification is usually attained in ordinary threshing and hulling. On the other hand, crotalaria has exceedingly hard seed that is difficult to abrase or scarify and special treatment is required to make it readily germinable.

TYPES OF SCARIFIERS

The treatment of hard seed to induce quick germination is commonly known as scarifying and machines used to accomplish this purpose are called scarifiers. These machines differ widely in design and construction, but scarification is usually effected either by an abrasive surface or by impact. With an abrasive, the seed is usually brought in contact with the rough surface either by air blast or by centrifugal force or a combination of these principles. Centrifugal force is usually relied upon when the seed coats are ruptured by impact. Such machines have been designed for commercial use in scarifying seed in somewhat large quantities, but have been usually too expensive for the small farmer.

The extension of the use of crotalaria and *Lespedeza sericia* has made it especially desirable to have a simple and cheap scarifier that can be made available for home use on the farm, and it was largely with this in mind that the experimental work reported in this publication was undertaken. This has resulted in the development of a barrel scarifier, in which gravel is used as the abrasive.[2] This method has proved to be effective and promises to serve well for scarifying small lots of seed.

Besides an inexpensive and simple scarifier for home use, there has also been need for a machine that would meet the needs of the agronomist in introducing new and improved varieties of legumes. A machine for this use must be easy to clean, and to operate, and cause a minimum of sprout injury. The Bureau of Plant Industry developed a scarifier of the modified cylinder type [3] which has been used very successfully for several years in hulling and scarifying. This machine is, however, of high construction cost. A scarifier of simpler design has been developed for this purpose in the disk scarifier described herein.

[2] So far as known, gravel as an abrasive in scarifying seed was first used in the United States by R. B. Carr, of the Sandhill Experiment Station, Columbia, S. C., and the results of some of his experiments are included in this publication.

[3] This machine was developed by A. T. Stone, of the Division of Forage Crops and Diseases. His experience was used to advantage in designing the barrel and disk scarifiers described in this circular.

SPROUT INJURY

Seeds with very hard seed coats are difficult to scarify without occasioning more or less sprout injury. This term is applied to injury done the germ of the seed during the process of scarifying, so that although the sprout starts to grow it does not continue and develop into a plant. In the case of crotalaria sprout injury is much higher than in most other seeds, but such injury may be caused to any seed. The amount of sprout injury depends in part upon the type, adjustment, and mechanical condition of the scarifier used. The problem of sprout injury, which has been recognized but recently, makes the problem of scarifying and the development of satisfactory scarifiers more difficult.

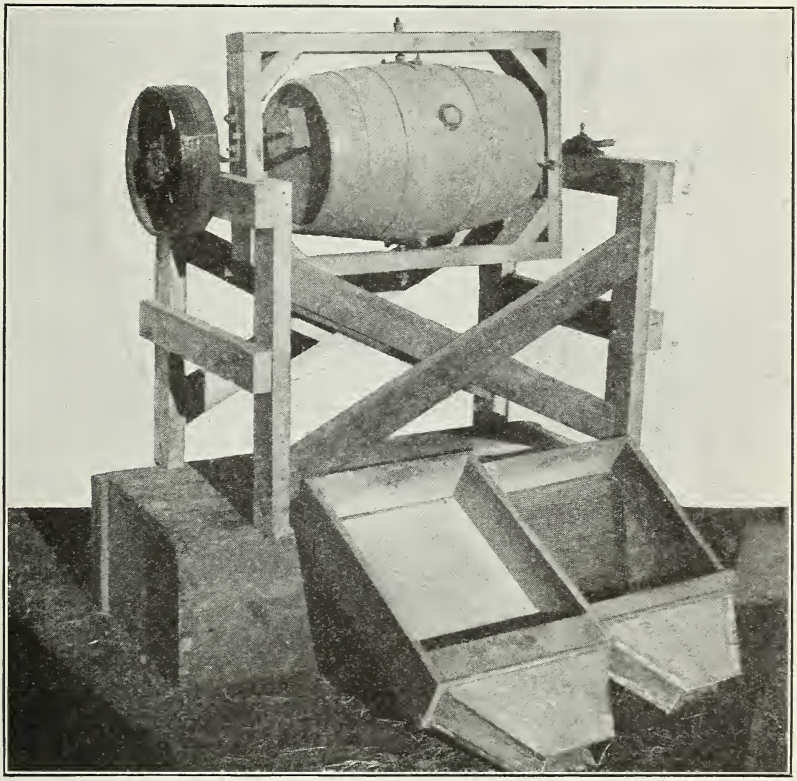

FIGURE 1.—The barrel scarifier used for most of the tests with this type of machine.

The efficiency of any scarifier must be determined not by the number of seeds that will start to germinate, but by the number that will continue to grow and produce plants. In other words, in testing any scarifier the amount of sprout injury must be determined. In the following tabulations of results of the experiments, the percentages of germination, sprout injury, and hard seed are indicated in all cases.

BARREL SCARIFIER

CONSTRUCTION AND OPERATION

In the development of the use of gravel as an abrasive for scarifying seed, a 15-gallon barrel was mounted in a frame as illustrated in figure 1. This barrel or keg, constructed of heavy material, pre-

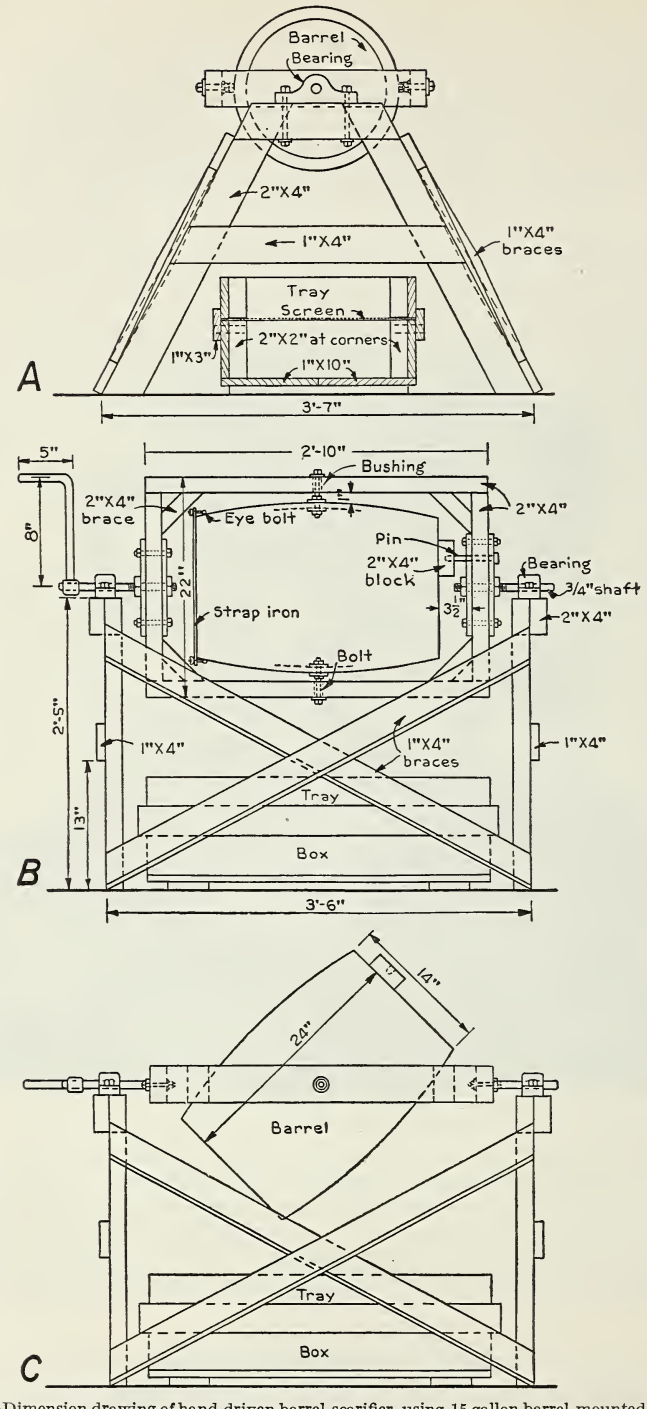

FIGURE 2.—Dimension drawing of hand-driven barrel scarifier, using 15-gallon barrel mounted in a rotating frame so it can be tilted for filling and emptying.

viously had been used as a liquid container. Figure 2 gives the dimensions of a scarifier constructed by the Department for hand operation. The frame in this is somewhat less rugged than would be desirable for a power-driven machine. The scarifier might be simplified by mounting the barrel on a shaft extending through the ends and providing a door in the side for filling and emptying. Mounted on a shaft in this manner, however, the barrel would not be so easily emptied as when mounted in a frame.

In separating the seed from the gravel, the contents of the barrel are dumped onto a screen-bottom tray placed directly over a box for collecting the seed, as indicated in figure 1, *C* and figure 2. Screen wire (hardware cloth) of ¼-inch mesh was found satisfactory when gravel with particles approximately ½ inch in diameter or larger was used. When the seed and gravel are dumped on such a screen to a depth of not more than 3 or 4 inches, a little agitation will cause the seed to fall through into the box.

In the experiments with the tumbling barrel it was found that germination was affected by a number of variables, including the speed at which the barrel was revolved, the size of gravel used, the quantity of gravel, the proportions of seed and gravel, and the length of time the seed were subjected to the tumbling action. If the barrel was revolved at a speed at which centrifugal action caused the seed and gravel to whirl with the barrel, little or no scarifying action resulted. When the barrel was revolved at a speed greatly below that which caused whirling of the contents, the scarifying action was so slow that a considerable time was required to accomplish the desired results.

The following tabulation gives the range of speed recommended for barrels of different sizes. The maximum speed as indicated in the tabulation is slightly below the speed at which centrifugal action will cause some of the seed and gravel to revolve with the barrel.

Diameter of barrel (feet):	*Range in speed (revolutions per minute)*
1	60 to 75
1.5	50 to 60
2	40 to 50
3	30 to 40
4	25 to 35

Barrel sizes are not in all cases standardized and the dimensions of few, if any, would agree with those indicated. However, the following formula sometimes used in calculating the critical speed of ball mills may be used for determining the critical speed of a barrel scarifier:

$$S=\sqrt{\frac{54}{R}}$$

S=speed of the barrel in revolutions per minute
R=radius of barrel in feet

Ball mills are often operated at about 75 percent of the critical speed, or speed at which the material in the mill would centrifuge if it did not slip.

GRAVEL SIZES AND RATIOS OF SEED TO GRAVEL

The gravel used was what is generally known as "river-run gravel" and was graded into three sizes, namely, that passing a ¾-inch mesh but retained on a ½-inch mesh screen, that passing a 1-inch but

retained on a ¾-inch mesh, and that passing a 1¼-inch but retained on a 1-inch mesh screen. The gravel used in the barrel scarifier is shown in figure 3.

If extremely hard or sharp gravel is used as the abrasive, the seed should be examined carefully and germination tests made before any great portion of a given lot of seed is scarified, in order to prevent

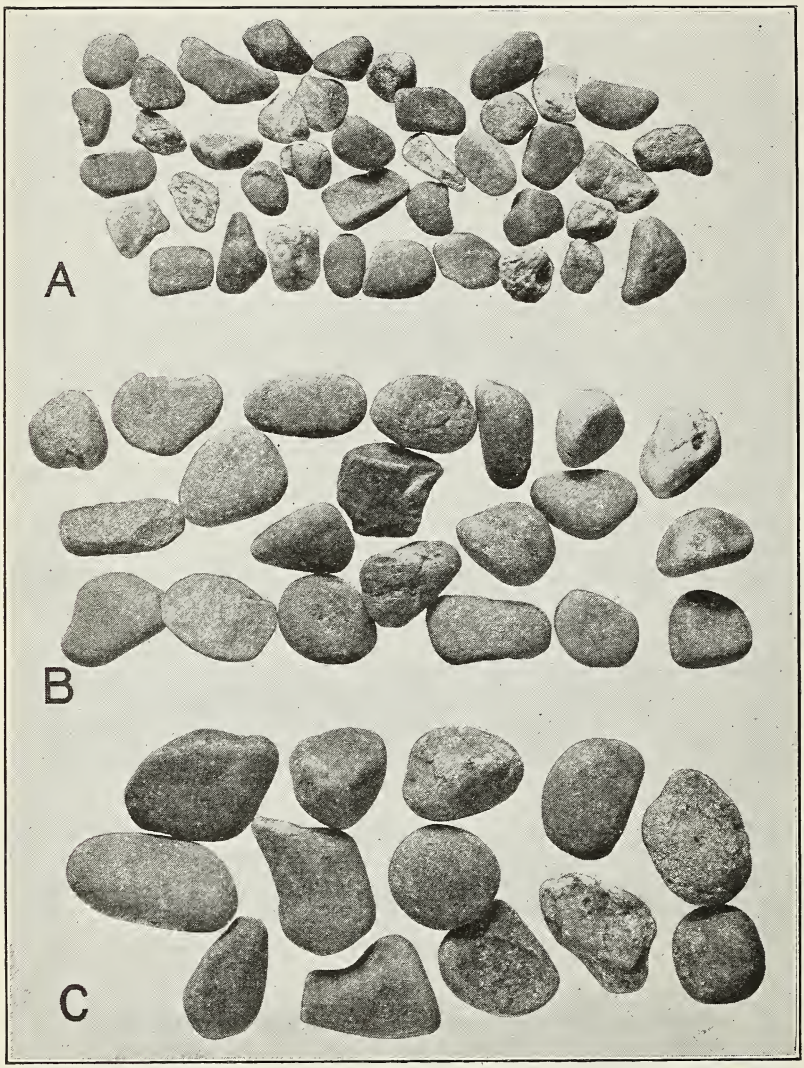

FIGURE 3.—Gravel used in barrel scarifier: *A*, ½ to ¾ inch; *B*, ¾ to 1 inch; *C*, 1 to 1¼ inch.

possible injury to the entire lot. Before using, the gravel should be screened to proper size, washed, and allowed to dry. It should also be rescreened frequently, as small particles break off, forming a dust which collects on the seed and is otherwise irritating to the operator.

The same quantity of gravel (76 pounds) was used in practically all of the tests. The size of the barrel was such that 76 pounds of

gravel filled it nearly half full. Previous tests had indicated that a barrel should be not more than half full of gravel and seed for best results. A series of tests were made, however, to determine the quantity of seed which should be mixed with the gravel for best results.

In the experiments with crotalaria, 8-, 16-, and 24-pound lots of seed were used with each of the three sizes of gravel. The proportions of crotalaria seed to gravel by weight approximated 1:9.5, 1:5 and 1:3; and by volume 1:6, 1:3, and 1:2. In scarifying lespedeza and sweetclover,[4] 4-, 8-, 12-, and 16-pound lots of each kind of seed were

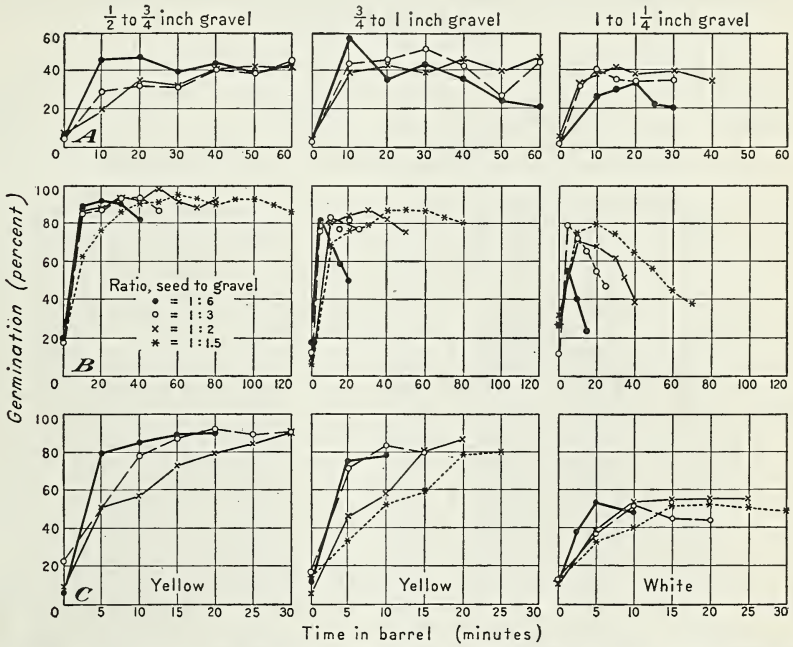

FIGURE 4.—Germination of seed scarified in a barrel with different sizes of gravel, with different seed-gravel ratios by volume, and for different periods of time: *A*, *Crotaleria striata*; *B*, *Lespedeza sericea*; *C*, sweetclover. Symbols of ratio of seed to gravel apply to *A*, *B*, and *C*.

used. With lespedeza and sweetclover the proportion of seed to gravel by weight approximated 1:19, 1:9.5, 1:6, and 1:5, and by volume 1:6, 1:3, 1:2, and 1:1.5.

In scarifying crotalaria the seed were subjected to the action of the gravel until there was clear evidence of injury to the seed. With lespedeza and sweetclover, the seed were tumbled until practically all were hulled. Samples were taken at 5- or 10-minute intervals during the scarifying operation for germination tests, in order to determine the time required for scarification. With sweetclover and lespedeza, unhulled seed were used for the check samples (samples to show germination before hulling or scarifying) and hulled seed for those in determining time requirements.

Table 1 shows the germination of the seed as affected by size of gravel and proportion of seed to gravel; in figure 4 the findings are

[4] The sweetclover seed used in these experiments was *Melilotus officinalis* and *M. alba*.

shown graphically. As the quantity of seed in the barrel was increased, the time required for scarification in most cases was increased. Theoretically the volume of seed mixed with the gravel should be slightly greater than the voids in the gravel. On this basis, probably 40 to 50 percent as much seed as gravel, by volume, should be used. The tests indicate that 75 to 100 percent, by volume, of seed may be used to advantage under certain conditions. The time required for scarification will, of course, be greater with equal parts of seed and gravel than with 50 percent as much seed, but not twice as long in all cases.

TABLE 1.—*Germination and sprout injury of seed scarified in a 15-gallon barrel with 76 pounds of gravel*

CROTALARIA STRIATA

Gravel size, inches	Seed	Time in barrel	Germination [1]	Hard seed	Sprout injury	Gravel size, inches	Seed	Time in barrel	Germination [1]	Hard seed	Sprout injury
	Pounds	*Minutes*	*Percent*	*Percent*	*Percent*		*Pounds*	*Minutes*	*Percent*	*Percent*	*Percent*
		0	6.0	77.0	1.0			0	4.0	78.5	1.5
		10	46.0	20.5	11.0			10	44.0	18.5	13.0
		20	47.0	9.0	11.0			20	46.0	12.0	14.5
	8	30	39.5	10.5	15.0		16	30	51.5	6.0	18.5
		40	44.0	4.0	11.5			40	43.5	6.0	23.5
		50	39.5	4.5	23.0			50	27.5	4.5	23.0
		60	44.0	4.5	15.0			60	44.5	3.0	14.5
		0	4.0	77.0	2.5	¾–1		0	5.0	78.5	1.0
		10	29.0	41.5	7.5			10	39.5	33.0	9.5
		20	32.0	31.0	9.5			20	43.0	26.0	8.5
	16	30	31.5	21.0	8.0		24	30	39.0	24.0	15.5
		40	40.5	15.5	7.0			40	46.0	13.5	14.5
½–¾		50	39.0	13.0	10.5			50	40.0	15.5	15.0
		60	45.0	13.0	10.0			60	47.5	10.5	14.5
		70	44.0	14.0	13.5			0	3.5	77.5	2.0
		0	7.5	77.0	1.0			10	27.0	7.0	24.5
		10	19.5	58.5	5.5			15	30.5	.5	27.5
		20	34.5	39.0	9.5		8	20	33.5	.5	33.5
		30	32.5	34.5	6.5			25	22.5	.5	34.0
	24	40	41.0	25.5	9.5			30	21.0	.0	33.5
		50	42.0	22.5	14.0			0	2.5	80.5	.5
		60	42.0	21.5	13.5			5	32.0	35.0	10.0
		70	38.5	16.0	8.0			10	41.0	22.5	11.0
		80	41.0	13.0	16.5		16	15	36.0	6.5	13.5
		0	4.5	80.0	4.0	1–1¼		20	34.5	11.0	24.5
		10	58.0	6.0	21.5			30	35.5	2.0	19.5
		20	36.5	4.0	35.0			0	6.0	78.5	.0
¾–1	8	30	44.0	2.0	38.0			5	33.5	45.5	5.0
		40	36.5	1.0	46.5			10	38.5	30.0	10.0
		50	25.0	1.0	52.5		24	15	42.0	19.5	15.0
		60	21.5	0.0	45.0			20	38.5	20.5	16.0
								30	40.5	16.0	23.5
								40	35.0	10.5	31.0

YELLOW SWEETCLOVER

		0.0	5.5	90.5	0.0			0	12.5	83.5	0.0
		5	79.0	15.0	1.5		4	5	76.0	10.0	12.0
	4	10	85.0	8.5	3.0			10	79.0	.5	17.0
		15	89.0	3.5	4.0			0	17.0	78.5	.0
		20	90.5	0.0	6.0			5	72.5	24.5	1.5
		0	22.5	72.0	.0		8	10	84.0	3.5	7.5
		10	78.0	13.5	3.0			15	80.5	.5	16.0
		15	88.0	4.5	4.0			0	6.5	90.0	.0
	8	20	92.0	2.5	3.0			5	47.0	45.0	3.5
½–¾		25	89.5	.5	7.5	¾–1		10	58.5	30.5	3.0
		30	91.0	.5	5.5		12	15	81.5	10.0	4.5
		0	9.5	84.5	.0			20	87.0	3.0	4.0
		5	51.0	45.5	.0			0	15.5	76.0	.0
		10	56.5	36.5	1.5			5	34.5	56.5	2.0
	12	15	73.0	16.5	5.0			10	53.5	37.5	.5
		20	79.5	11.0	1.5		16	15	60.0	27.5	4.5
		25	84.0	8.0	1.5			20	79.5	13.0	.5
		30	91.0	4.0	3.5			25	81.0	8.0	8.0

[1] Seedlings capable of producing normal plants.

TABLE 1.—*Germination and sprout injury of seed scarified in a 15-gallon barrel with 76 pounds of gravel*—Continued

WHITE SWEETCLOVER

Gravel size, inches	Seed	Time in barrel	Germination [1]	Hard seed	Sprout injury
	Pounds	*Minutes*	*Per cent*	*Per cent*	*Per cent*
1–1¼	4	0.0	11.5	58.9	4.5
		2.5	39.5	27.0	10.0
		5.0	55.0	11.0	19.5
		10.0	49.5	1.5	29.0
	8	0	14.5	63.0	2.5
		5	38.5	27.5	10.5
		10	53.0	12.0	16.5
		15	47.0	3.5	23.5
		20	46.0	1.5	23.0
	12	0	11.5	58.5	.5
		5	40.5	32.0	2.0
1–1¼	12	10	55.0	23.5	6.5
		15	56.5	19.0	10.5
		20	56.5	8.0	15.5
		25	57.0	.5	19.0
	16	0	13.0	61.5	4.0
		5	34.5	41.0	5.0
		10	41.5	32.0	7.0
		15	53.0	23.5	11.0
		20	54.5	18.5	9.5
		25	52.5	7.0	20.5
		30	51.5	6.0	17.0

LESPEDEZA SERICEA

Gravel size (inches)	Seed (unhulled)	Time in barrel	Hulled seed	Germination [1]	Hard seed	Sprout injury
	Pounds	*Minutes*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
½–¾	4	0	0	22.0	73.0	0.0
		10	50	88.5	4.0	1.0
		20	85	91.5	1.0	4.0
		30	90	90.0	.0	5.0
		40	(2)	82.0	.0	13.0
	8	0	0	17.0	81.5	.0
		10	30	85.5	5.0	.5
		20	50	87.0	5.5	3.0
		30	75	93.0	2.0	2.0
		40	90	93.0	.5	4.0
		50	98	87.0	.5	7.0
	12	0	0	18.5	77.5	.5
		10	20	86.0	9.0	1.0
		20	35	87.5	9.5	1.0
		30	45	93.0	4.0	1.5
		40	60	91.5	1.5	3.0
		50	80	98.0	.5	1.0
		60	90	91.5	1.5	4.0
		70	95	88.5	.5	3.5
		80	99	91.5	.0	4.0
	16	0	0	16.5	77.0	2.5
		10	20	62.0	26.0	.5
		20	25	76.0	17.0	.5
		30	30	85.5	7.5	2.0
		40	35	90.5	6.0	1.5
		50	45	91.0	3.5	2.0
		60	55	95.0	2.0	1.0
		70	65	92.0	1.0	3.5
		80	75	90.5	2.0	3.5
		90	80	93.0	.0	5.0
		100	90	93.0	1.5	2.0
		110	95	90.0	.0	7.0
		120	99	86.0	1.0	8.5
¾–1	4	0	0	18.0	75.0	2.5
		5	60	82.0	5.0	7.0
		10	90	71.0	.0	21.0
		15	(2)	59.0	.0	35.5
		20	100	50.5	.0	32.5
	8	0	0	12.5	85.5	1.0
		5	30	76.0	12.5	4.0
		10	60	83.5	5.5	6.5
		15	85	77.0	2.0	11.5
		20	95	82.0	.5	8.0
		25	(2)	77.5	.0	13.0
¾–1	12	0	0	22.0	73.0	0.0
		10	35	80.5	12.0	3.0
		20	60	84.5	5.0	2.5
		30	85	87.5	1.0	3.5
		40	97	83.0	.0	8.0
		50	(2)	75.5	.0	15.5
	16	0	0	7.5	85.5	1.5
		10	20	69.5	19.0	1.5
		20	35	77.0	12.5	2.5
		30	50	79.5	9.0	2.0
		40	65	87.5	4.5	2.5
		50	80	87.5	.5	7.0
		60	95	87.0	.5	4.0
		70	98	83.5	.0	7.0
		80	(2)	81.0	.0	14.0
1–1¼	4	0	0	27.0	66.0	3.5
		5	65	56.0	3.0	25.0
		10	95	40.5	.0	29.0
		15	(2)	24.0	.0	28.5
	8	0	0	12.5	80.0	1.0
		5	40	79.5	9.5	5.0
		10	70	73.5	4.0	9.0
		15	90	66.0	.5	14.0
		20	95	55.0	.0	23.5
		25	(2)	47.5	.0	29.0
	12	0	0	32.5	63.0	2.5
		10	10	72.0	8.5	9.5
		20	65	69.0	1.5	16.5
		30	90	62.5	1.0	19.5
		35	95	52.5	.5	27.5
		40	(2)	39.0	.0	37.5
	16	0	0	28.0	62.5	4.5
		10	10	75.5	11.0	5.5
		20	25	80.5	5.0	5.0
		30	45	75.0	2.0	11.5
		40	60	65.5	3.5	19.0
		50	80	56.5	1.5	23.5
		60	95	45.5	.0	27.5
		70	(2)	39.0	.5	17.5

[1] Seedlings capable of producing normal plants.
[2] Trace unhulled.

SCARIFYING CROTALARIA

The seed were grown in Puerto Rico in 1930, and germinated approximately 5 percent before scarifying. The indications were that either it was a poor lot of seed or some seed had deteriorated due to age. Of the 11 samples obtained before scarifying (check samples), an average of only 82.4 percent of the seed was viable. The maximum germination obtained with the barrel scarifier was 58 percent after 10 minutes of tumbling with 8 pounds of seed and 76 pounds of ¾- to 1-inch gravel. The 58-percent germination is probably not significant, as with this and two other exceptions the maximum germination obtained for individual tests ranged from 40 to 50 percent as is shown in tables 1 and 2.

Figure 4 shows that as the size of gravel is increased the proportion of seed to gravel should also be increased to prevent severe sprout injury. With ½- to ¾-inch gravel considerably better results were obtained with 8 pounds of seed than with either 16 or 24 pounds. With ¾- to 1-inch gravel there was little difference in germination as affected by proportion of seed except that the germination fell off at a more rapid rate after 20 or 30 minutes treatment with 8 pounds than with either 16 or 24 pounds of seed. When 1- to 1¼-inch gravel was used, better results were obtained with 16 and 24 pounds than with 8 pounds of seed.

TABLE 2.—*Duration of treatment which gave best results with different sizes of gravel and different ratios of seed to gravel, in scarifying Crotalaria striata seed*

Size of gravel (inches)	Volume ratio of seed to gravel	Time in barrel	Germination	Hard seed	Sprout injury
		Minutes	*Percent*	*Percent*	*Percent*
½–¾	1 : 6	10 to 20	46.0 to 47.0	9.0 to 20.5	11.0 to 11.0
	1 : 3	40 to 60	40.5 to 45.0	13.0 to 15.5	7.0 to 10.0
	1 : 2	40 to 60	41.0 to 42.0	21.5 to 25.5	9.5 to 13.5
¾–1	1 : 6	5 to 10	—— to 58.2	—— to 6.0	—— to 21.5
	1 : 3	20 to 30	46.0 to 51.5	6.0 to 12.0	14.5 to 18.5
	1: 2	40 to 60	46.0 to 47.5	10.5 to 15.5	14.5 to 15.0
1–1¼	1 : 6	(1)			
	1 : 3	10 to 15	36.0 to 41.2	6.5 to 22.5	11.5 to 13.5
	1 : 2	15 to 20	38.5 to 42.0	19.5 to 20.5	15.0 to 16.0

[1] Probably less than 5 minutes. The first sample taken, after 10 minutes in the barrel, showed severe sprout injury (table 7).

As far as the data show, the quantity of gravel in the barrel, provided of course that it is not more than half full, has little effect on time required for scarification if the same ratio of seed to gravel is maintained. For example, there was little difference in the effectiveness of the scarifier with 76 pounds of gravel and 16 pounds of crotalaria seed, with 50 pounds of gravel and 10 pounds of seed, or with 25 pounds of gravel and 5 pounds of seed, as is shown in table 3. This would indicate that for maximum capacity the barrel should be approximately half full of gravel and seed, but that the machine is as effective if operated with the barrel less than half full with the same ratio of gravel and seed.

TABLE 3.—*Germination and sprout injury of Crotalaria striata seed as affected by quantity of seed and gravel in barrel* [1]

Quantity of gravel (pounds)	Quantity of seed	Time in barrel	Germination	Hard seed	Sprout injury
	Pounds	*Minutes*	*Percent*	*Percent*	*Percent*
76	16	0	4.0	77.0	2.5
		10	29.0	41.5	7.5
		20	32.0	31.0	9.5
		30	31.5	21.0	8.0
		40	40.5	15.5	7.0
		50	39.0	13.0	10.5
		60	45.0	13.0	10.0
50	10	0	6.0	76.5	2.0
		10	26.5	40.5	7.0
		20	42.5	29.5	12.5
		30	41.0	21.0	10.5
		40	45.0	14.0	13.0
		50	46.5	12.0	13.0
		60	49.0	6.0	19.5
25	5	0	6.0	68.5	----------
		10	25.0	51.0	3.0
		20	38.5	34.5	10.5
		30	39.5	33.0	13.0
		40	42.5	20.5	10.5
		50	55.0	16.5	15.0
		60	50.0	14.0	14.0

[1] Size of gravel ½ to ¾ inch.

SCARIFYING SWEETCLOVER

The best results obtained with sweetclover seed were with the ½- to ¾-inch gravel, as shown in table 1 and figure 4. Both yellow sweetclover (*Melilotus officinalis*) and white sweetclover (*M. alba*) seed were used, but there was considerable difference in the viability of these two lots of seed. The yellow sweetclover was grown near North Ridgeville, Ohio, in 1930, and the white sweetclover was obtained from a commercial seed dealer. The North Ridgeville seed germinated 12.7 percent with 82.2 percent of hard seed, indicating 94.9 percent of viable seed. The seed obtained from the commercial firm germinated approximately 12.6 percent with 60.2 percent of hard seed, making a total of 72.8 percent of viable seed.

TABLE 4.—*Duration of treatment which gave best results with different sizes of gravel and different ratios of seed to gravel, in scarifying sweetclover seed* [1]

Size of gravel (inches)	Volume ratio of seed to gravel	Time in barrel	Germination	Hard seed	Sprout injury
	Ratio	*Minutes*	*Percent*	*Percent*	*Percent*
½–¾	1:6	15 to 20	89.0 to 90.5	0.0 to 3.5	4.0 to 6.0
	1:3	20 to 30	91.0 to 92.0	.5 to 2.5	3.0 to 5.5
	1:2	30 to 40	91.0 to —	4.0 to —	3.5 to —
¾–1	1:6	5 to 10	76.0 to 79.0	.5 to 10.0	12.0 to 17.0
	1:3	10 to 15	80.5 to 84.0	.5 to 3.5	7.5 to 16.0
	1:2	15 to 20	81.5 to 87.0	3.0 to 10.0	4.0 to 4.5
	1:1.5	25 to 30	81.0 to —	8.0 to —	8.0 to —
1–1¼	1:6	5 to 10	49.5 to 55.0	1.5 to 11.0	19.5 to 29.5
	1:3	10 to 15	47.0 to 53.0	3.5 to 12.0	16.5 to 23.5
	1:2	20 to 25	56.5 to 57.0	.5 to 8.0	15.5 to 19.0
	1:1.5	20 to 25	52.5 to 54.5	7.0 to 18.5	9.5 to 20.5

[1] Approximately 95 percent of seed used with ½- to ¾- and ¾- to 1-inch gravel and 72.8 percent of those used with 1- to 1¼-inch gravel were viable.

In comparing results of germination tests as affected by size of gravel it should be remembered that the sweetclover seed used with the 1- to 1¼-inch gravel were inferior to those used with the smaller

sizes. Had the same lot of seed been used for all tests, it is thought that there would have been only a small difference in germination of seed scarified with the ¾- to 1- and 1- to 1¼-inch sizes of gravel. There is, however, a clear indication that higher germination and less sprout injury were obtained with the ½- to ¾-inch gravel than with larger sizes in scarifying sweetclover. Table 4 shows the time required for best results with different sizes of gravel and proportions of seed to gravel.

SCARIFYING LESPEDEZA

The 4-, 12-, and 16-pound lots used with 1- to 1¼-inch gravel germinated 29.1 percent with 63.8 percent of hard seed before hulling. These seed were obtained from a commercial seed firm and the indications were that approximately 93 percent were viable. The seed used with ½- to ¾-, ¾- to 1-, and the 8-pound lot with 1- to 1¼-inch gravel were grown on the Arlington Experiment Farm at Rosslyn, Va. The experiment-station seed germinated 14.9 percent with 80.2 percent of hard seed before hulling, indicating a viability of 95.1 percent. This difference in viability is slight, and it is doubtful if variations in results obtained with the two lots of seed could be attributed to viability. There might be some difference in time required for hulling and scarifying, however, as none of the seed obtained from the commercial firm was hulled when received and approximately 10 percent by weight of the experiment-station seed was hulled in threshing.

The ½- to ¾-inch gravel gave much better results with Lespedeza than either the ¾- to 1- or the 1- to 1¼-inch sizes, as is shown in table 1 and figure 4. As previously stated, the Lespedeza seed were subjected to the scarifying action of the gravel until practically all of the seed were hulled. Some sprout injury resulted in hulling the last 5 to 10 percent of the seed with ½- to ¾-inch gravel but the injury was slight. With large gravel, especially the 1- to 1¼-inch, extreme sprout injury resulted in some cases before all of the seed were hulled. These results indicate that if gravel larger than ½- to ¾-inch is used the hulled seed should be screened out at frequent intervals. In cleaning the seed taken from the barrel for samples during the hulling and scarifying operation, the hulls were not put back in the barrel. Samples were taken from 4 to 12 times for each lot of lespedeza seed, and by the end of each test a large percentage of the hulls had been removed which probably accounted for some of the sprout injury.

In scarifying Lespedeza seed the time required for scarification depends in part upon the size of gravel and proportion of seed and gravel, as was the case with crotalaria and with sweetclover. The time required is less with large than with small gravel, and increases with an increase in ratio of seed and gravel though not in direct proportion to the increase in quantity of seed. The time required for best results with different sizes of gravel and varied proportions of seed and gravel in scarifying *Lespedeza sericea* seed is shown in table 5.

TABLE 5.—*Duration of treatment which gave best results with different sizes of gravel and different ratios of seed to gravel, in scarifying Lespedeza sericea seed*

Size of gravel (inches)	Volume ratio of seed to gravel	Time in barrel	Hulled seed	Germination	Hard seed	Sprout injury
	Ratio	*Minutes*	*Percent*	*Percent*	*Percent*	*Percent*
½–¾	1:6	20 to 30	85 to 90	90.0 to 91.5	0.0 to 1.0	4.0 to 5.0
	1:3	30 to 40	75 to 90	93.0 to 93.0	.5 to 2.0	2.0 to 4.0
	1:2	40 to 50	60 to 80	91.5 to 98.0	.5 to 1.5	1.0 to 3.0
	1:1.5	60 to 70	55 to 65	92.0 to 95.0	1.0 to 2.0	1.0 to 3.5
¾—1	1:6	5	60	82.0	5.0	7.0
	1:3	10 to 15	60 to 85	77.0 to 83.5	2.0 to 5.5	6.5 to 11.5
	1:2	20 to 30	60 to 85	84.5 to 87.5	1.0 to 8.0	2.5 to 3.5
	1:1.5	40 to 50	65 to 80	87.5 to 87.5	.5 to 4.5	2.5 to 7.0
1–1¼	1:6	5	65	56.0	3.0	25.5
	1:3	5 to 10	40 to 70	73.8 to 79.5	4.0 to 9.5	5.0 to 9.0
	1:2	10 to 20	10 to 65	69.0 to 72.0	1.5 to 8.5	9.5 to 16.5
	1:1.5	20 to 30	25 to 45	75.0 to 80.5	2.0 to 8.0	8.0 to 11.5

CONCRETE MIXER

Only a few tests were made with concrete mixers in scarifying seed, but the indications were that the same proportion of seed and gravel and approximately the same size gravel should be used as with the barrel scarifier. Ordinary farm-type mixers were used, and it was necessary to operate them with the axis of rotation more nearly horizontal than is customary in mixing concrete. With the mixer in such position the seed and gravel fall a greater distance when picked up by the mixing blades, and as a result the scarifying action is more rapid than when the mixer is set at a steeper angle. One of the mixers used had a rated capacity of about 4 cubic feet and the mixing bowl was driven at 20 revolutions per minute; the other mixer was somewhat larger but was driven at approximately the same speed.

Table 6 gives the germination and sprout injury of crotalaria seed scarified in a concrete mixer at Arlington Farm, and table 7 the effectiveness of quantity of gravel on scarification with a concrete mixer at the Sandhill Experiment Station. With 75 pounds of stone and 75 pounds of seed a germination of 64.5 percent was obtained with 2 hours of treatment. When 100 pounds of gravel was used with 75 pounds of seed, approximately the same germination was obtained in about 65 minutes. By increasing the quantity of gravel to 125 pounds, only 30 to 40 minutes were required. No more reduction in time was obtained, however, by a further increase in quantity of stone. With 150 pounds of stone and 75 pounds of seed, probably the mixer was filled beyond its effective capacity for scarification. With this exception the tables show that as the proportion of gravel to seed is increased the time required for scarification is decreased, which is in accordance with results obtained with the barrel scarifier.

TABLE 6.—*Germination and sprout injury of 24 pounds Crotalaria striata seed scarified in a concrete mixer with 76 pounds of ½- to ¾-inch gravel as the abrasive at Arlington Farm, Va.*[1]

Time in mixer (minutes)	Germination	Hard seed	Sprout injury	Time in mixer (minutes)	Germination	Hard seed	Sprout injury
	Percent	*Percent*	*Percent*		*Percent*	*Percent*	*Percent*
0	5.0	73.5	4.0	80	54.0	14.0	12.0
20	38.0	36.0	7.0	100	49.0	8.5	19.5
40	45.0	25.5	15.0	120	45.5	11.0	27.0
60	49.5	16.0	16.0				

[1] Same lot of seed as those used with the barrel scarifier.

TABLE 7.—*Germination and sprout injury of 75 pound lots of Crotalaria striata seed scarified in a concrete mixer with different amounts of gravel as an abrasive at the Sandhill Experiment Station, Columbia, S. C.*[1]

Quantity of gravel (pounds)[2]	Time in mixer	Germination	Hard seed	Sprout injury	Quantity of (gravel pounds)[2]	Time in mixer	Germination	Hard seed	Sprout injury
	Minutes	*Percent*	*Percent*	*Percent*		*Minutes*	*Percent*	*Percent*	*Percent*
	10	21.0	68.0	3.0		60	62.5	27.5	4.0
	20	25.5	60.5	2.0	100	70	67.5	22.0	3.5
	30	32.5	57.5	2.0		80	60.0	24.0	3.5
	40	32.5	53.5	2.0		10	36.5	54.5	1.0
	50	44.5	44.5	2.5		20	51.0	43.5	1.0
	60	50.0	33.5	3.5		30	47.0	39.0	3.0
75	70	47.0	36.0	5.0	125	40	68.0	23.0	3.0
	80	58.5	29.0	4.5		50	71.0	20.0	5.0
	90	48.5	36.0	1.5		60	73.0	15.0	6.5
	100	59.0	28.0	3.5		70	77.0	8.0	7.5
	110	63.0	25.5	6.8		80	74.0	9.5	5.5
	120	64.5	20.0	5.0		10	44.5	48.5	2.5
	10	26.0	68.5	1.0		20	57.0	34.0	4.8
	20	40.0	52.0	1.5	150	30	56.5	33.0	6.0
100	30	50.5	39.0	2.0		40	69.5	16.0	6.0
	40	50.5	43.0	1.0		50	68.0	22.5	2.0
	50	56.0	33.0	3.0					

[1] Crotalaria seed grown on the Sandhill Experiment Station and tests made by R. B. Carr, Bureau of Plant Industry.

[2] Gravel not screened but particles varied from approximately 1 to 1¼ inches in diameter.

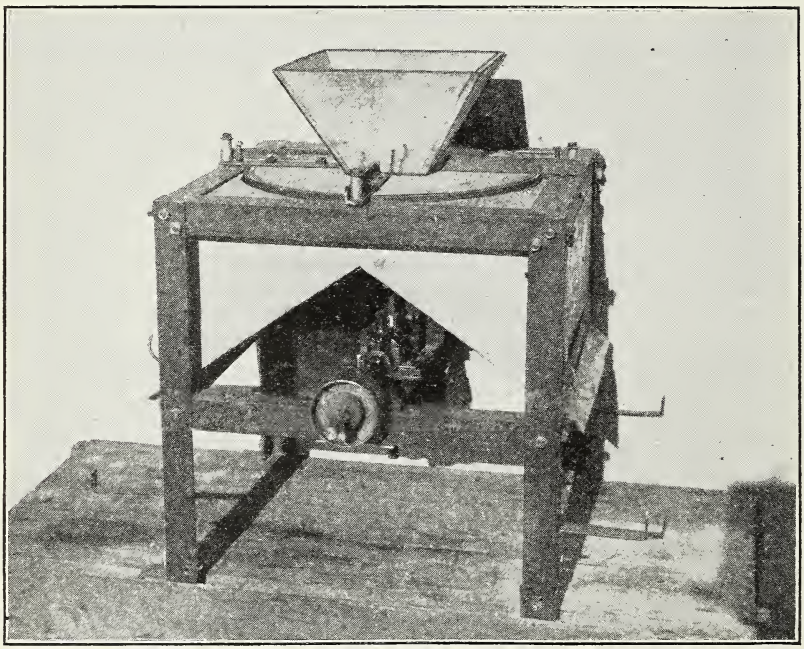

FIGURE 5.—The disk-type scarifier.

DISK SCARIFIER

Hulling or scarifying in the disk machine (figs. 5 and 6) is accomplished by friction between two horizontal disks, of which the top disk is stationary. The top surface of the bottom disk is covered with an abrasive and the bottom surface of the top disk with rubber. The top disk holds the seed down against the abrasive surface and

the rubber acts as a cushion to minimize injury to the seed. A vertical adjustment is provided for the top disk to vary the clearance between the disks as may be necessary for different sizes of seed. From the hopper on top of the machine the seed pass through an opening in the center of the top disk onto the revolving bottom disk, and are forced outward between the disks by centrifugal force. The seed, after clearing the disks, are deflected downward by a draper attached to the edge of the top disk and fall into a hopper or may be conveyed to a sack or other container.

CONSTRUCTION

In the experimental scarifier, the top disk was approximately 19 inches and the lower disk 18 inches in diameter. The difference in

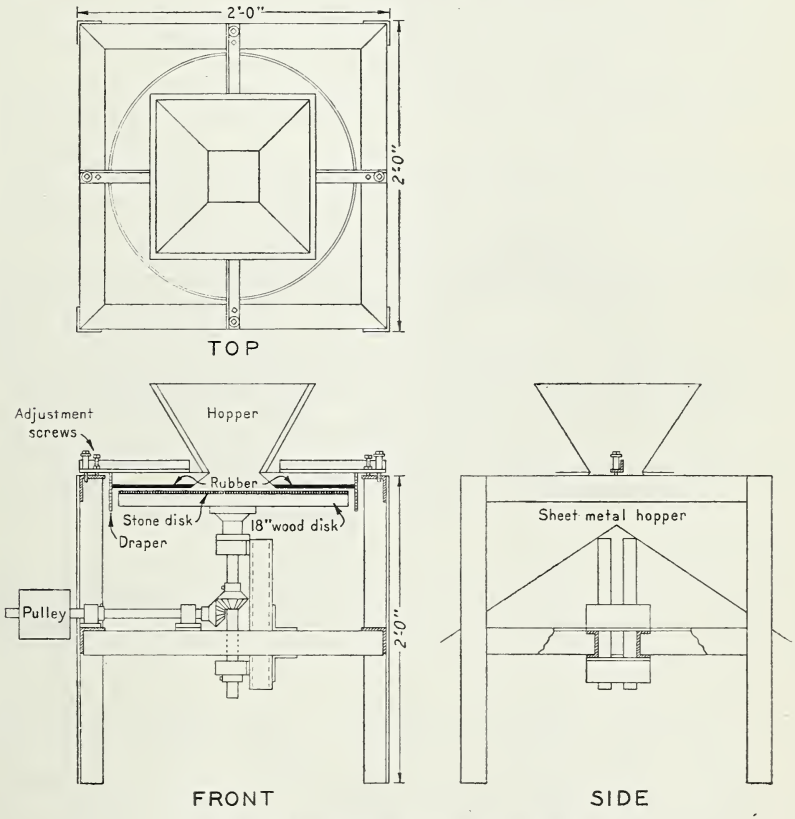

FIGURE 6.—Essential design features of disk scarifier.

size provided a space for the seed to pass between the draper and the outer edge of the lower disk. The disks were made of plywood and were approximately 1 inch thick. The central hole through the top disk was 4 inches in diameter at the upper surface and 6 inches in diameter at the lower surface. The size of the opening on the underside of the top disk had a decided influence on the capacity of the scarifier; the larger the hole the greater the quantity of seed that passed through the machine in a given length of time at a given disk

speed and setting. While no tests were made to determine the exact size of the opening with reference to the size of the disks used, a 6-inch hole seemed to give satisfactory performance. If the hole were made too large, the efficiency of the machine would be impaired, as the only part of the scarifying surface which is effective is that against which the seed are held by the rubber.

In hulling or scarifying small seed such as *Lespedeza sericea*, it is necessary to operate the disks with but little clearance. For this reason it is essential that the lower surface of the top disk and the top surface of the lower disk be parallel. Before the drive shaft is attached to the lower disk, the collar should be rigidly attached to the shaft and the face of the collar and the end of the shaft turned true and smooth in a lathe. In case there should be a slight wabble in the disk after the shaft is attached, shims may be used under the collar or the top surface of the disk may be turned true in a lathe. After the shaft is attached, the edge of the disk should also be turned true to prevent vibration at high speed.

In the experimental machine as is shown in figure 6, the angle-iron supports for the top disk are tapped to receive the adjusting screws. It is suggested, however, that a short piece of strap iron about ½ inch thick be bolted on each angle iron and tapped to receive the adjusting screws, as it is difficult to get a snug fit with threads in a thin piece of metal. It is also suggested that a cut-off valve be placed in the throat of the hopper for controlling the rate of feed.

Carpenter's glue was found to be satisfactory in cementing the abrasive (stone disk) to the wooden disk. The rubber for the top disk may be attached with small finishing nails or wire brads. By sinking the heads of finishing nails slightly below the surface of the rubber, the latter soon closes in over the heads and makes a smooth surface with no tendency to pull out. If nails with large heads are used the pressure exerted by the rubber under the heads will usually force them out far enough to strike the revolving disk. Rubber cement or glue may also be used in conjunction with wire brads, but extreme care is necessary to obtain a good bond between the rubber and the disk.

Sheet rubber generally known as pure gum rubber proved to be satisfactory on the top disk. A sheet ¼ inch thick trimmed to fit the disk was used on the experimental machine, and the hole through the center was cut at about the same angle as the hole through the wood portion of the disk.

Garnet paper [5] was first tried as an abrasive, but it was not entirely satisfactory because the efficiency of the machine varied with the condition of the paper. However, a stone disk ¼ inch thick appeared to fulfill the requirements. This was obtained from a manufacturer of abrasive materials and was made especially for the job, the degree of abrasiveness being described as having about the same effect as no. 2 garnet paper would have when similarly used. Perforated sheet metal might also answer as an abrasive for certain kinds of seed, but no attempt should be made to punch the metal by hand. This is not only difficult to do satisfactorily, but the metal is forced out of shape so that a uniform surface is almost impossible to obtain.

[5] A paper similar to sandpaper, commonly used in commercial wood shops.

For operating the scarifier, power was obtained from an overhead line shaft driven by a 3-horsepower electric motor, and a secondary shaft with gears was required for driving the lower disk. This necessitated a more rigid frame than if the scarifier could have been belted directly to the motor. With the belt drive, however, care would be necessary in lining up the pulleys as the face of the motor pulley would be horizontal and that of the scarifier vertical.

The frame of the experimental scarifier is of such size and design that the seed, after passing between the disks, are discharged on two sides of the machine. The bottom of the hopper underneath the disk is sloped in opposite directions in order to provide space for the bearings, bearing supports, and gears.

OPERATION

Results of tests made with the disk machine show that speed and spacing of the disks, nature of abrasive, and kind of rubber all influence the effectiveness and capacity of the machine. It was found that the capacity was, in some cases, twice as great with the abrasive on the bottom disk and the rubber on the top as when they were in reverse positions.

The difference in capacity was doubtless due to slippage of the seed on the rubber. With the abrasive on the lower disk the centifugal action was more effective in forcing the seed outward between the disks. The germination and sprout injury of sweetclover, lespedeza, and crotalaria seed as affected by disk speed and clearance, with stone on the lower disk and gum rubber on the top disk, is shown in table 8.

TABLE 8.—*Germination and sprout injury of sweetclover, lespedeza, and crotalaria seed as affected by disk speed and clearance in hulling and scarifying*

WHITE SWEETCLOVER

Operation	Times through	Speed of disk	Clearance of disk	Capacity of machine	Germination	Hard seed	Sprout injury
	Number	*Revolutions per minute*	*Inches*	*Pounds per hour*	*Percent*	*Percent*	*Percent*
	0	0		0	10.5	67.0	4.0
Hulling	1	300		80.4	49.0	29.5	4.5
Scarifying	1	300		500.7	56.0	17.0	5.5
	2	300		557.1	60.5	15.0	6.0
	3	300		518.4	71.5	6.0	9.5
	4	300	0.028	471.4	66.5	6.5	8.5
	0	0		0	8.5	68.5	3.0
Hulling	1	500		130.4	68.5	4.5	9.0
Scarifying [1]	1	500		710.5	76.0	1.5	8.5
	2	500		699.2	74.0	.5	14.0
	3	500		653.4	78.0	.5	6.0
	4	500		640.8	77.0	0	10.0
	0	0		0	9.0	66.5	3.0
Hulling	1	300		180.0	30.5	44.5	6.5
Scarifying	1	300		900.0	39.5	42.5	4.0
	2	300		933.4	44.0	39.0	4.0
	3	300		969.2	38.0	32.5	8.0
	4	300	.042	933.2	50.0	27.5	4.5
	0	0		0	7.0	70.5	4.5
Hulling	1	500		219.5	65.5	9.0	8.0
Scarifying	1	500		857.2	81.0	3.5	5.0
	2	500		1,125.0	80.0	2.0	6.5
	3	500		1,107.0	79.5	3.5	7.0
	4	500		985.9	80.0	1.5	5.0
	0	0		0	4.5	71.0	6.0
Hulling	1	700		818.2	58.0	23.0	7.0
Scarifying	1	700	.056	2,214.0	74.0	6.0	7.0
	2	700		2,178.0	76.5	3.5	3.5
	3	700		2,563.2	78.0	1.0	4.5
	4	700		2,520.0	74.5	2.5	8.0

[1] Trace unhulled.

TABLE 8.—*Germination and sprout injury of sweetclover, lespedeza, and crotalaria seed as affected by disk speed and clearance in hulling and scarifying*—Contd.

LESPEDEZA SERICEA

Operation	Times through	Speed of disk	Clearance of disk	Capacity of machine	Germination	Hard seed	Sprout injury
	Number	*Revolutions per minute*	*Inches*	*Pounds per hour*	*Percent*	*Percent*	*Percent*
	0	0		0	23.5	72.0	3.5
Hulling	1	300		113.9	62.0	34.0	1.5
Scarifying [1]	1	300		576.0	63.0	36.0	0
	2	300		628.3	65.0	30.0	2.5
	3	300		596.3	72.0	23.5	.5
	4	300		586.8	73.0	21.5	1.5
	0	0	0.014	0	25.5	73.0	0
Hulling	1	500		233.7	68.0	30.0	0
Scarifying	1	500		720.0	89.5	8.0	0
	2	500		746.5	93.5	2.0	.5
	3	500		721.9	94.0	2.0	1.0
	4	500		750.0	96.5	1.0	0
	0	0		0	29.5	68.5	0
Hulling	1	300		163.6	38.0	57.0	0
Scarifying [2]	1	300		630.0	41.5	57.5	0
	2	300		744.7	54.0	44.5	0
	3	300		624.0	55.5	44.0	0
	4	300		568.4	57.0	38.0	0
	0	0		0	25.5	69.5	0
Hulling	1	500	.028	144.0	78.5	12.5	0
Scarifying [1]	1	500		847.0	83.5	11.0	0
	2	500		663.4	91.5	3.5	.5
	3	500		623.4	90.5	6.5	.5
	4	500		613.6	94.0	2.5	0
	0	0		0	26.5	73.0	0
	1	648		500	69.5	27.0	0
Hulling [3]	0	0	.042	0	26.0	72.5	0
	1	634		486.5	71.0	25.5	0
	0	0	.056	0	23.5	75.0	0
	1	700		947.3	51.0	46.5	0

CROTALARIA STRIATA

	0	0		0	7.0	73.5	4.5
	1	300		375.0	17.0	52.0	7.5
	2	300		494.6	37.0	35.5	8.0
Scarifying	3	300		562.8	42.0	22.0	15.5
	4	300		540.0	50.0	10.0	16.5
	5	300	0.028	542.5	55.0	4.5	16.5
	0	0		0	5.5	79.5	4.0
	1	500		545.4	28.0	37.0	10.0
	2	500		641.3	48.0	10.0	18.5
Scarifying	3	500		684.0	63.0	2.5	12.0
	4	500		694.4	57.0	1.5	20.0
	5	500		666.0	52.5	0	20.0
	0	0		0	5.0	76.0	5.0
	1	300		486.5	8.5	74.5	5.5
	2	300		618.4	24.5	48.0	8.0
Scarifying	3	300		633.3	28.0	42.0	15.0
	4	300		641.1	42.5	25.5	11.0
	5	300	.042	648.0	48.0	20.0	16.0
	0	0		0	7.0	76.0	2.5
	1	500		750.0	21.5	49.0	11.0
	2	500		936.0	41.5	27.0	12.0
Scarifying	3	500		1,018.5	52.0	12.0	13.0
	4	500		1,125.6	58.5	4.0	19.5
	5	500		1,172.5	61.0	.5	12.5
	0	0		0	9.0	77.0	3.5
	1	300		514.3	10.0	70.5	5.0
	2	300		808.3	10.0	67.5	5.5
Scarifying	3	300		798.4	17.0	57.0	7.5
	4	300		787.0	27.0	49.5	5.0
	5	300	.056	767.4	27.5	35.5	11.5
	0	0		0	1.0	76.5	4.0
	1	500		857.1	10.0	65.0	8.5
	2	500		922.7	24.0	53.0	8.0
Scarifying	3	500		1,018.6	36.5	32.5	9.5
	4	500		1,018.6	41.0	21.5	13.0
	5	500		1,068.7	53.5	14.0	13.5

[1] Trace unhulled.
[2] Approximately 14 percent unhulled.
[3] Approximately 58 percent unhulled.

DISK SPEED AND CLEARANCE

SCARIFYING WHITE SWEETCLOVER

The white sweetclover seed used for these tests was obtained from a commercial seed firm and germinated approximately 7.9 percent before hulling with 68.7 percent of hard seed. These results indicate 76.6 percent viable seed.

With a disk clearance of approximately 0.028 [6] inch an increase in disk speed of from approximately 300 to 500 revolutions per minute resulted in increased capacity of 62.2 percent in hulling. This increase in capacity was slightly less than the increase in speed, but better results were obtained at the higher speed. In scarifying, the increase in speed resulted in only a 32-percent increase in capacity, but the percentage germination of the seed was higher after one scarifying at 500 revolutions per minute than it was after four operations at 300 revolutions per minute.

A similar increase in capacity was obtained by an increase of from approximately 300 to 500 revolutions per minute with a disk clearance of about 0.042 inch but the germination was much better at the high speed, as is shown in table 8. An attempt was made to hull sweetclover seed at a disk speed of about 700 revolutions per minute with disk clearances of 0.28 and 0.042 inch, respectively, but the power required was beyond the capacity of the 3-horsepower motor used on the line shaft. The motor would, however, operate the machine at this speed with a disk clearance of 0.056 inch. The hulling capacity of the machine with sweetclover seed at 0.056-inch disk clearance and 700 revolutions per minute was 818.2 pounds per hour; with hulled seed the capacity averaged 2,369 pounds per hour.

These tests show that as the speed of the disk is increased the clearance should also be increased, for best results. The data do not show the extent to which the clearance may be increased with reference to disk speed.

SCARIFYING CROTALARIA

The *Crotalaria striata* seed used germinated approximately 5.7 percent before scarifying, with 76.4 percent of hard seed. On this basis the viability was approximately 82.1 percent.

In scarifying crotalaria seed, tests were made at disk clearances of 0.028, 0.042, and 0.056 inch at approximately 300 and 500 revolutions per minute (table 8). With the disk set at 0.028 inch the machine had an average capacity of approximately 503 pounds per hour at a disk speed of 300 revolutions per minute and maximum germination was obtained after 5 scarifying operations. At this disk setting, but with a speed of 500 revolutions per minute, maximum germination was obtained after 3 scarifying operations and the capacity was increased to an average of 646 pounds per hour for each time through. With a disk clearance of 0.042 inch and a speed of 300 revolutions per minute, evidently 5 operations were not sufficient to obtain maximum germination of the seed; at a speed of 500 revolutions per minute, however, probably maximum germination was obtained after 4 or 5 operations, and the capacity of the machine was approximately 1,000 pounds per hour for each operation as compared with 605 pounds at 300 revolutions per minute. A clearance of 0.056 inch appears to be

[6] Disk clearance was adjusted by one-quarter turns of the adjustment screws on the top disk, which screws had 18 threads per inch.

too great for a disk speed of either 300 or 500 revolutions per minute. The better results were obtained, however, at the higher speed.

The data obtained seem to show that, within the range of these experiments, as the speed of the disk is increased the clearance should also be increased for best results. So far as the data show, there is no definite relation between disk clearance or speed and sprout injury.

SCARIFYING LESPEDEZA

The *Lespedeza sericea* seed used with the disk machine were obtained from a commercial seed house and the viability was high. Before the seed were hulled they germinated 25.2 percent with 72.3 percent of hard seed, indicating 97.5 percent viable.

Lespedeza seed were more difficult to hull and scarify than sweet-cover seed, necessitating close setting of the disks. The sprout injury, however, was in all cases very slight, as is shown in table 8.

With a disk clearance of 0.014 inch and a speed of 300 revolutions per minute the machine hulled the seed at the rate of about 114 pounds and scarified at an average rate of 597 pounds per hour. At the same setting but with a speed of 500 revolutions per minute hulling was accomplished at the rate of 234 pounds and scarifying at an average rate of about 735 pounds per hour. For complete scarification at a speed of 300 revolutions per minute four operations were not sufficient, but at 500 revolutions per minute two scarifying operations were sufficient.

After 4 scarifying operations at a disk clearance of 0.028 inch and a speed of 300 revolutions per minute, 57 percent of the seed germinated, with 38 percent of hard seed. With the same setting but at a speed of 500 revolutions per minute 91.5 percent of the seed germinated after 2 scarifying operations and 94.0 after 4 such operations. There was, however, only a slight increase in capacity in scarifying, and a decrease in rate of hulling. A further increase in disk speed resulted in an increase in capacity for hulling, but available power was not sufficient for scarifying at the higher speed.

DETERIORATION OF SCARIFIED SEED WITH AGE

In order to determine whether or not scarified seed deteriorate more rapidly than seed not scarified, such seed were kept through several years and germination tests made each season. The results are given in tables 9 to 12.

In the case of several species of *Crotalaria* (table 9), there was no appreciable deterioration in 3 years. The normal life period of crotalaria seed is comparatively long, and the scarified crotalaria seed retained its vitality well. Nevertheless, general observation with other seeds supports the belief that scarified crotalaria seed will deteriorate sooner than unscarified seed. It is also shown by this experiment that the time of germination of crotalaria seed lightly scarified is advanced materially even though it will not germinate the first year. Thus seed that has been scarified and still shows a high percentage of hard seed will germinate much better in the second year than seed not so scarified.

TABLE 9.—*Deterioration with age of scarified and unscarified crotalaria seed*

Species	Scarifier [1]	1931		1932			1933			1934		
		Germination	Hard seed	Germination	Hard seed	Sprout injury	Germination	Hard seed	Sprout injury	Germination	Hard seed	Sprout injury
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Crotalaria striata	None	5	93	10.5	86	0	13	85	2			
	S	45	25	59	13.5	6	57	9.8	10	61.3	10.0	9.5
	A	34	52	67.5	5	23	71	5	21.5	72.5	2.5	18.5
	A	33	18.5	36.5	2.5	33	38	3	31	27.0	1.3	24.8
Crotalaria anagyroides	None			8	46.5		8	35.5	3	7.0	41.0	3.0
	S			65.5	5		64.5	7.5	6.5	62.5	4.5	9.0
	None			38	57.5		53.5	38.5	1.5	51.0	40.5	2.0
	S			95	0		87.5	0	5	80.0	0	12.0
Crotalaria grantiana	None			57	32		50	37.5	2	60.0	23.0	2.0
	S			83	4		84	1	5.5	81.0	1.5	7.5
Crotalaria intermedia	S			72	10		84	3.5	3.5	84.5	3.0	.5
Crotalaria usaramoensis	None			22.5	41		22.5	30.5	0	26.0	50.0	2.0
	S			61.5	18.5		77.5	5.5	0	76.0	5.5	3.0
Crotalaria spectabilis	None			27	67.5		28	65.5	0			
	S			85.5	3		93	1.5	1			
Crotalaria spectabilis	None	28	51									
	S	75.5	1	73	0	11.5	81	0	7.5	79.5	0	8.0
	A	48	1.5	47	1.5	17.5	55	0	22.5	47.0	0	20.5

[1] The letters S and A represent 2 different scarifiers used.

TABLE 10.—*Deterioration with age of scarified and unscarified white sweetclover seed*

Time subsequent to initial condition test (years)	Unscarified			Scarified		
	Germination	Hard seed	Total viable	Germination	Hard seed	Total viable
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
0	14.5	80.0	94.5	78.0	8.0	86.0
1	15.0	78.0	93.0	71.0	8.5	79.5
2	10.5	82.5	93.0	47.0	9.0	56.0
3	11.0	82.5	93.5	48.0	6.5	54.5
4	10.0	79.0	89.0	30.5	6.0	36.5

In the case of sweetclover the unscarified seed deteriorate very slowly and often the loss in germinability is less than 1 percent a year for many years. Most of this loss is in the soft seed which constitutes 15 to 20 percent at harvesting. The hard seed retain their viability for a very long time. Seed 20 years or more old often germinate well when scarified. Old seed, however, as soon as scarified begin to deteriorate rapidly and are almost worthless after a few months.

Scarified sweetclover seed, even when fresh, do not retain their viability long. Typically, such seed decline 5 to 10 percent the first year, 20 to 40 percent additional the second year, and may germinate as little as 25 percent by the end of the third year (table 10).

Part, at least, of this heavy loss of viability may be due to sprout injury (table 11). Sprout-injured seeds appear to deteriorate both more quickly and more completely than seeds which have not been injured. If, as frequently happens, the sprout-injured seed are not detected in the germination test but are included with the viable seed, there may appear to be a severe loss of germinability during the first 2 years. If the sprout injury had been detected, or if the seed had been scarified on a machine that did not cause much sprout injury, the loss of viability with age would not have appeared so great.

TABLE 11.—*Deterioration of scarified white sweetclover seed with age and degree of sprout injury*

Time subsequent to scarification (months)	Germination		Hard seed		Sprout injury		Apparently viable [1]		Actually viable [2]	
	Lot A	Lot B	Lot A	Lot B	Lot A	Lot B	Lot A	Lot B	Lot A	Lot B
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
0	75.5	62.5	10.5	6.5	5.0	18.0	91.0	87.0	86.0	69.0
6	74.0	60.5	11.0	6.5	5.0	16.0	90.0	83.0	85.0	67.0
12	72.5	62.0	9.5	5.5	5.5	14.5	87.0	82.0	82.0	67.5
18	66.0	56.5	10.0	6.0	3.0	8.0	79.0	70.5	76.0	62.5
24	63.5	52.0	9.5	5.0	1.5	4.0	74.5	61.0	73.0	57.0

[1] Seed with injured sprouts considered as viable.
[2] Seed with injured sprouts not considered as viable.

Scarified seed of *Lespedeza sericea* lose viability more rapidly than seed stored in the hull. This is shown by the record of several lots of seed harvested in different years and scarified at definite dates. The seed were scarified in a different scarifier than that described in this circular, but there is no reason to believe that results would have been different if another scarifier had been used. The results are given in table 12.

TABLE 12.—*Deterioration with age of scarified Lespedeza sericea seed tested in the spring of 1934*

Crop year harvested	Date scarified	Laboratory test		Greenhouse test; germination in 10 days
		Germination	Hard seed	
		Percent	*Percent*	*Percent*
1928	January 1930	6.75	16.5	6.75
	March 1934	72.25	9.75	67.75
1930	January 1931	30.75	22	32.5
	March 1934	80.5	1	82
	February 1931	44.5	11.75	41.5
1931	February 1932	72	15.25	62
1931	1932	68.5	21.5	56
1932	1933	84.0	6	70.5

In every case scarified seed lost viability in storage whereas unscarified seed did not.

SUMMARY

Extension in the production of legume crops that have a high percentage of hard seed has created a need for simple and cheap means of scarification. The scarification must not only break the seed coat, but also must avoid causing excessive sprout injury.

An inexpensive scarifier was devised, of barrel type, which is easy to build and suitable for farm use in scarifying small quantities of seed. River-run gravel was used as the abrasive. A farm-type concrete mixer also was used as a barrel-type scarifier, with satisfactory results.

A disk-type scarifier of larger capacity, but more costly, was designed and found to be easily operated, easily cleaned, and to cause little sprout injury. In this a stone disk was the abrasive, revolving close under a stationary disk faced with gum rubber.

Experiments were made with seed of yellow and white sweetclover, *Lespedeza sericea*, and *Crotolaria striata*, to determine the effects of these scarifiers on germination, hard seed, and sprout injury.

Best results with the barrel scarifier were obtained when the gravel was of size to pass a screen of ¾-inch mesh and be retained on a screen of ½-inch mesh, and when the volume of seed was one-half to two-thirds that of the gravel. The conclusion seems warranted that the best ratio of seed to gravel, by volume, is 1:2 to 1:1. The greater the ratio of seed to gravel, the longer the time required for scarification. The seed and gravel should fill the barrel, not more than half, and the speed of rotation should be slightly less than will make some of the seed and gravel whirl with the barrel.

The capacity of the disk scarifier generally, but not always, increased with the speed of the disk and with the clearance between the disks. To maintain the germination percentage with increase in clearance, it was always necessary to increase the disk speed.

Experiments as to deterioration of seed with age seemed to show that scarified seed do not remain viable as long as unscarified seed.

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